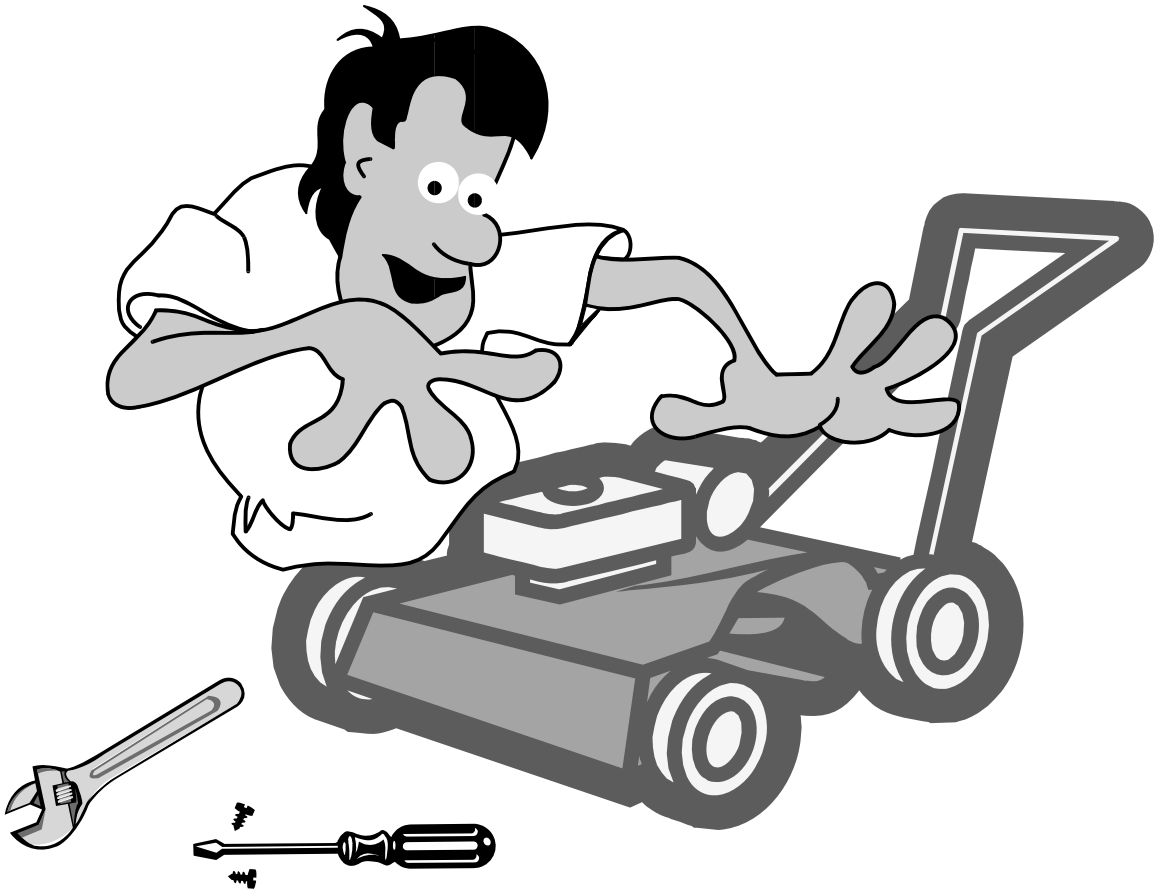

Rebuilding Small Engines

Member's Manual
Printed 2005

Manitoba Agriculture, Food and Rural Initiatives
www.gov.mb.ca/agriculture/

4-H Motto

Learn to do by doing.

4-H Pledge

I pledge
My HEAD to clearer thinking
My HEART to greater loyalty
My HANDS to larger service
My HEALTH to better living
For my club, my community and my country.

4-H Quality Equation Principles

Quality People
Promote responsibility, respect, trust, honesty, fairness, sportsmanship, citizenship, teamwork and caring.
Quality Experiences
Provide members with personal development and skill development experiences.
Quality Projects
Promote and value quality effort.
Promote high quality, safe food production within industry standards.

Table of Contents

TOPIC	PAGE
Project Completion Requirements	2
Introduction	2
Project Evaluation	3
Member's Workbook	4
Leader's Guide	9
Project Mtg. 1 – Review of Small Engine Basics	10
Project Mtg. 2 – Engine Disassembly/Ordering Parts	12
Project Mtg. 3 – Engine Reassembly Procedures	15
Project Mtg. 4 – How Small Engines Work-Lubrication System	20
Project Mtg. 5 – How Small Engines Work-Ignition System	27
Project Mtg. 6 – How Small Engines Work-Crankcase Breathers	35
Project Mtg. 7 – How Small Engines Work-Fuel System	39
Project Mtg. 8 – How Small Engines Work-Cooling System & Speed Control	46
Project Mtg. 9 – How Small Engines Work- Electric Starters & Batteries	50
Project Mtg. 10 – Troubleshooting	57
Project Mtg. 11 – Storing Small Engines	67

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Acknowledgement to our writers:
Larry Clark
Gary Sallows
Kim Beilby

Project Completion Requirements

For completion of this project, each member must:

- Complete and display the “My 4-H Record” at achievement.
- Complete all the “Smooth Running” activities in the member’s portion of the manual.
    - Before Photo – pg 4
    - Replacement Parts Shopping List – pg 4
    - Engine Reassembly Checklist – pg 5
    - Oil Change Calendar – pg 5
    - Ignition Repair List – pg 5
    - Crankcase Breather Repair List – pg 6
    - Carburetor Countdown – pg 6
    - Speed Control – pg 6
    - Pros & Cons of Electric Starters – pg 7
    - Troubleshooting – pg 7
    - After Photo – pg 8
- Display the small engine you or your group worked on during the year.

Introduction

This project is about how to take apart and rebuild small engines to get them running smoothly.

The first section of this manual – “Member’s Workbook” – (pages 4 to 8) is for members to record their activities in. The second section is for leaders – “Leader’s Guide” – giving them activities and tips on how to make this a great “learn to do by doing” project. This project requires a minimum of eleven project meetings to complete. Of course, you and your leader can always explore the world of small engines further by creating more adventures.

PROJECT EVALUATION
Rebuilding Small Engines

Please help us to make sure the 4-H program provides quality projects. Fill out this form as you work through the book. Your answers will be used to improve the project. After you are done your project, mail this form to:

Provincial 4-H Office
Manitoba Agriculture, Food and Rural Initiatives
1129 Queens Avenue
Brandon MB R7A 1L9

Who are you? _____ member _____ leader _____ parent

1. Why did you choose to take this project? _____

_____

2. What was the best part of this book?_____

3. In this book, what things were too hard or didn't work?_____

_____

4. What are some neat ideas that would make this book more exciting? _____

_____

_____

5. Anything else you would like to tell us?_____

_____

In case we need to find out more, you may want to add your name:

Name: _____ Phone #: _____ Email: _____

Before Photo:

Replacement Parts Shopping List

Engine Specs: _____

Type: _____

Name: _____

Model Number: _____

Parts needed	Price
Total	

Engine Reassembly Checklist

Check any of the following that you had to complete in overhauling your small engine.

	Yes	No
Valve lapping		
Installing valve springs		
Replacing piston rings		
Installing piston in cylinder		
Reglazing cylinder walls		

Oil Change Calendar

I need to change oil in my small engine every _____.

My small engine takes this type of oil: _____.

Ignition Repair List

I needed to do the following to have my ignition system operating.

_____

_____

_____

_____

_____

_____

Crankcase Breather Repair List

I had to do the following to have my crankcase breather operating properly:

_____

_____

_____

_____

_____

Carburetor Countdown

My small engine has a (check one)

_____ float-type carburetor

_____ suction-lift type carburetor

_____ diaphragm carburetor

My small engine burns the following type of fuel:

_____

_____

Speed Control

My governor is a _____ governor.

Draw sketch of governor linkage.

Pros & Cons of Electric Starters

Pros	Cons

Troubleshooting

1. To do effective trouble shooting, you must remember what three things?

(1) _____

(2) _____

(3) _____

2. List two things that could be wrong if your engine did not develop compression.

(1) _____

(2) _____

(3) _____

3. List three reasons an engine might lose power and stop

(1) _____

(2) _____

(3) _____

After Photo

Introduction

This project is about how to disassemble and repair an engine, as well as giving you an opportunity to explore engine functions in detail.

The sequence of Project meetings: key concepts in this project are as follows:

Project Meeting 1 - Review of Small Engine Basics

Project Meeting 2 - Engine Disassembly/Ordering Parts

Project Meeting 3 - Engine Reassembly Procedures

Project Meeting 4 - How Small Engines Work: Lubrication System

Project Meeting 5 - How Small Engines Work: Ignition System

Project Meeting 6 - How Small Engines Work: Crankcase Breathers

Project Meeting 7 - How Small Engines Work: Fuel System

Project Meeting 8 - How Small Engines Work: Cooling System & Speed Control

Project Meeting 9 - Electric Starters & Batteries

Project Meeting 10 - Trouble Shooting

Project Meeting 11 - Storing Small Engines

Important Notes:

- Basic mechanical understanding is needed to successfully lead this project.
- This project is intended to be taken after the "Operation & Maintenance of Small Engines" project.
- Manufacturer's service manuals still play an important role in this project, so don't forget to use yours to help you learn about the engine you are using in this project. This manual is a guide and won't give you all the details.
  Service manuals can be obtained from dealers or engine companies if you do not have yours.
- For this project you should find a small engine (no bigger than 10 H.P.) which needs to be overhauled. Overhauled means that major repairs and checks as well as a total engine cleanup must be performed. The members may work on an engine individually or as a group. Use your judgement of the group, based on size of group, age and ability of members and the availability of engines to help determine the best situation.
- Depending on length of meeting and ability of members, some meetings may need to be split into two meetings.

Review of Small Engine Basics

Science Background for Leaders

Note - For this meeting you should have the "Operation & Maintenance of Small Engines" manual.

Key Objectives Highlighted by this Project Meeting:

* A basic review of all of "Operation & Maintenance of Small Engines" manual: parts, safety, tools and techniques.

Smooth Running 1: Basics from last year

Here are some questions. Answer them with your project leader and other members as you work around a small engine:

1) List tools you may use in working on small engines.
2) Name three important safety rules to remember when working on a small engine?
3) Explain how a small engine works. What are the differences between 2-cycle and 4-cycle engines?
4) What are the main parts of a small engine? What does each part do?
5) How do you start and stop a small engine?
6) Describe how to change oil in a 4-stroke/cycle engine.
7) What is the main function of a carburetor?

Describe how a spark plug works. When should it be replaced?

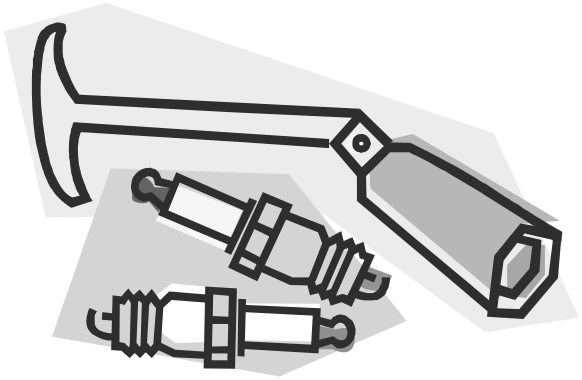
Smooth Running 2: Chart Your Course

Discuss what you would like to do as a project group this year to achieve project goals for Achievement Day.

Discuss finding the appropriate number of small engines to overhaul. Outline what tools are needed and appropriate dress for the next meeting.

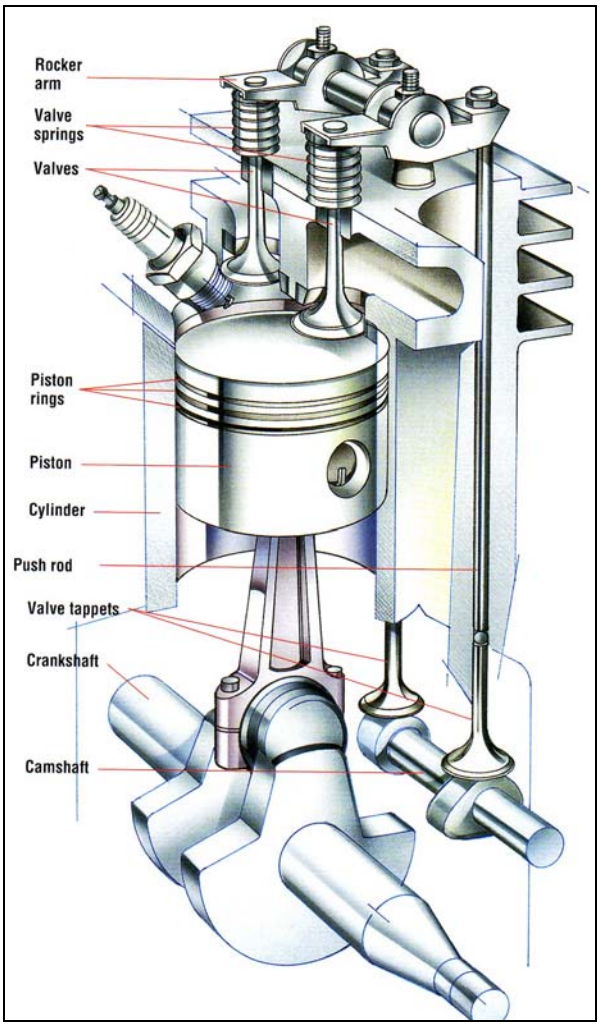
Q Tips
Quality Equation

Encourage group sizes so that each 4-H member can learn with their "hands". Show 4-H members "how" and help them when needed without "doing" it for them. "Learn to do by doing" is a very effective teaching method.



Engine Disassembly / Ordering Parts

Science Background for Leaders



Cutaway view of an overhead cam, one cylinder engine

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Know the steps in preparing for engine disassembly.
- Know the steps in engine disassembly
- Diagnose part wear and how to replace worn parts.

Smooth Running 1: Preparing your engine for disassembly

Required Materials:
Mat
Small engine
Tools
Shop supplies

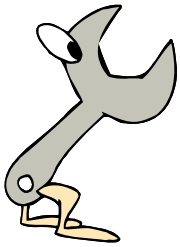
1) Drain the oil from the engine (4-stroke engine only).
2) Drain the gasoline from the fuel tank.
3) Disconnect the spark plug wire.
4) Obtain a box plus containers (plastic containers, small boxes, paper bags) to keep engine parts organized.
5) Locate a dealer who will help you order parts for your small engine.

Smooth Running 2: Steps in engine disassembly

1) Clean the outer surface of the engine. (It is important to remember that you should always use proper solvents and never use gasoline)
2) Mount the engine in a vise.
3) Remove parts - work carefully using the proper tools.
   - identify and remember where each part comes from. Draw pictures if you aren't sure you'll remember.
4) Clean all cleanable parts.

Smooth Running 3: Part Replacement

1) Diagnose part wear and replacements.
   - usual parts are gasket sets, piston rings; surfaces where a lot of movement occurs.
   - optional; check tolerances in the owner's guide specifications. These can tell you if your part needs replacing.
2) Purchase replacement parts.
   - copy down the model number, type of engine, and name of engine and part(s) needing replacement.
   - take the old part(s) along to double-check.
   - keep the sales bill, just in case the parts don't fit.
   - for the next meeting, have all replacement parts ready.



Smooth Running Program Reports

- Have members take a "Before" photo with their engine and mount in project book.
- Have members complete the "Replacement Parts Shopping List" on page 4.

Q Tips *Quality Equation*

Remember a quality experience is a safe experience. Model and expect safe behaviour including:

1. Keeping the shop clean
2. Using the proper tools correctly
3. Keeping yourself and others from dangerous situations
4. Using appropriate safety gear.
5. Placing all engine parts in labelled containers to keep them in order.
6. Using the owner's manual as a guide.

Engine Reassembly Procedure

Science Background for Leaders

This part of the manual will show you some of the things a mechanic would do to reassemble an engine. These steps are all a part of *overhauling*, or repairing, a small engine. The techniques described in the next sections are all basic; as project leader you should demonstrate how to do them to the members.

A. Valve Lapping (4-stroke):

- is a method of reseating valve heads to valve seats.
- things you will need
    - lapping compound
    - valve lapping tool (suction cup with wooden rod).
- mount cylinder head firmly in vise.
- clean surfaces of seats and valves.
- apply lapping compound to valve seat.
- place proper valve on seat (oil piston rod lightly).
- press suction cup firmly down on centre of valve head.
- spin and grind new surface onto valve head and valve seat. (This may take a very long time so be patient, a little extra time will mean a much better finished product)

View of the freshly lapped valve. Note the shiny outer surface, this is the part of the valve that makes contact with the seat.

- wipe off lapping compound, apply more, spin valve again.
- when smooth surface is obtained, stop.
- do other valve using the same method.
- be sure to clean all surfaces of lapping compound.
- check tappet clearances to the camshaft lobes (this is accomplished with a feeler gauge).

Courtesy of AAVIM
Athens, GA.

B. Installing Valve Springs (4-stroke):

- this job can be made much easier if you own a valve spring compressor.

or

Valve spring compressors

- things you will need:
  - two flat head screwdrivers
  - needle nose pliers
    or
  - valve spring compressor
- secure crankcase in a vise.
- place proper valve spring in casing.
- insert valve stem through spring (oil lightly).
- compress spring (with screwdrivers or compressor).
- insert spring holder (also called a "keeper"), lock into position (use needle nose pliers).
- Tap the completed spring assembly with a ball pean hammer, to ensure that the valve moves properly. Warning point the spring away from you as you tap it, if the sping holder (keeper) has not been installed correctly the spring could fly off and as it is under considerable pressure it could cause significant harm.
- repeat with other valve.
- install tappets and camshaft; test operation.

Intake and exhaust valves replaced

C. Replacing Piston Rings:

- piston rings seal the edge of cylinder wall to prevent oil leakage and to aid compression.
- things you will need:
  - piston ring expander
    or
  - snare wire (two 30 cm. lengths).

Piston ring compressor

Note:

- Be sure you install the piston rings in the proper order and direction (diagrams usually accompany a set of new rings).
- Be sure that the ends of the rings do not vertically line up

i. Piston ring expander:

- insert oil ring onto expander.
- place in proper slot (work from bottom ring up).
- repeat with other ring(s).

Piston ring compressor used to reinstall the rings

ii. Snare wire method:

- hook loops of snare wire over ends of rings.
- place ring in proper slot.
- repeat steps with other ring(s).

iii. If you have strong fingers, you can remove or install rings by hand. These methods also work when taking rings off.

D. Installing Piston in Cylinder:

- piston rings must be compressed to fit tightly
- things you will need:
  - piston ring compressor
    or
  - 30 cm x 10 cm piece of tin.
- attach connecting rod to piston.

- insert piston to point of first ring (make sure the direction is correct); oil lightly.
- compress rings.

Piston with new rings compressed, ready to be installed in the cylinder

- push piston down into cylinder with butt end of hammer.

Piston being re-installed in the cylinder

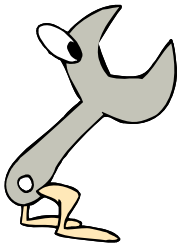
E. Reglazing Cylinder Walls:

- this process will ensure good piston ring contact to the cylinder wall.
- things you will need:
    - reglazing head
    - electric drill
    - goggles
- secure cylinder in a vise.
- lightly oil cylinder surface.
- prepare reglazing head (secure on drill).
- put on goggles.
- using an even up and down motion, reglaze the cylinder walls.
- an even cross hatch pattern should be present on the wall.
- clean surface of wall.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Do valve lapping.
- Install valve springs
- Replace piston rings
- Reglaze cylinder walls
- Install a piston into a cylinder



Smooth Running Program Reports

- Have members complete the "Engine Reassembly Checklist" on page 5.

Q Tips Quality Equation

For members to maximize their learning & enjoyment, they must have the appropriate tools, supplies, parts for each meeting. Look ahead to the next meeting to determine what supplies the members may need to bring or you may need to ensure they are available.

How Small Engines Work – Lubrication System

Science Background for Leaders

This section discusses the crankcase, gaskets and lubrication.

1. *Gaskets*

Gaskets have the job of sealing edges together so they will not leak under use. They are made from paper, cork and rubber compounds and are designed to hold under heavy working conditions. The gasket closely follows the contours of engine parts, so it is important that the proper gaskets are used, and gaskets should never be re-used.

When an engine is disassembled, the gaskets usually need to be replaced. You should always remember to purchase a new gasket set before you begin reassembling the small engine.

It is also essential that all parts of the block be thoroughly cleaned of any old gasket material. If this old gasket material is not cleaned off it may lead to leaks later on.

2. *Lubrication*

Your small engine needs to be lubricated properly because:

- Few small gasoline engines have an oil filter. Therefore, the oil should be changed frequently to remove metal particles, dirt, and sludge.
- The oil in air-cooled engines runs hotter than oil in water-cooled automobile engines.
- Most small engines operate near the ground. Small engines use small amounts of oil.
- Small engines usually operate at maximum power output.
- Small engines are lightweight and may vibrate more than large engines.
- Few small engines are given a warm-up period before a load is applied.

Oil may not reach the piston rings until after the engine has turned over several times. This lack of lubrication can cause two conditions: (1) rapid wear of the piston rings and cylinder walls, and (2) failure of the rings to seal off compression. Blow-by is increased. Blow-by sends harmful chemicals by the piston rings to the crankcase.

During choking, raw gasoline in the combustion chamber washes down the cylinder walls and worsens the conditions described in the previous paragraph. As this continues, oil in the crankcase is diluted and loses its effectiveness. After the engine warms, however, the gasoline is evaporated by heat.

Note: If you service your engine properly and keep it lubricated according to the manufacturer's recommendations, it will give you long and satisfactory service. The events described above only occur if you mistreat your engine.

Because oil can easily be contaminated with raw fuel, dirt, and oxidation products in small engines, it should be drained as often as recommended by the manufacturer.

Selecting Crankcase Oil

The cost of oil is the smallest of your operating expenses. Selecting the proper oil, however, is one of the most important decisions you make for your engine. The wrong type of oil may cause the piston to scar, warp, or crack.

The proper oil for lubricating your small engine may be described on the engine nameplate, in the operator's manual, or in lubrication guides produced by major oil manufacturers. Specifications will be given in two ratings:

1) API (American Petroleum Institute) Service classification - often called "type" of oil, and

2) SAE Viscosity - often called "viscosity grade".

All 4-cycle engines require a good type of oil - such as MS, SC or SD (API Classification). These oils are developed for engines operating under severe conditions such as numerous starts and stops, high temperatures and maximum loads and/or speeds. The following table describes the different A.P.I. classifications.

A.P.I. CRANKCASE OIL SERVICE CLASSIFICATIONS (1952 to date)	
APE Service Classifications	Service Conditions
SA(ML)	Service typical of gasoline and other spark-ignition engines used under *light and favorable operating conditions*. The engines having no special lubrication requirements.
SB(MM)	Service typical of gasoline and other spark-ignition engines used under *moderate to severe operating conditions*, but presenting problems of deposit or bearing-corrosion control when crankcase oil temperatures are high.
SC, SD SE(MS)	Service typical of gasoline and other spark-ignition engines used under *unfavorable, or severe, types of operating conditions*, and where there are special lubricating requirements for deposits, wear, or bearing corrosion control.

Oils with additives are recommended for most 4-cycle engines. Additives are chemicals put in the oil by the oil manufacturer to improve the quality of the oil. Some additives help prevent corrosion; some provide a better cushion between the moving parts; and some help prevent scuffing and reduce wear.

Detergent-dispersants are additives commonly called "detergents". Detergents in the oil help pick up dirt and sludge, and suspend them in the oil.

Note: Never add special oil treatments to your engine.If you use the proper oil, there is little good that they can do; and some can be harmful to your engine.

Manufacturers of 2-cycle engines generally recommend oils with special additives. Since 2-cycle engines are lubricated by mixing oil with the fuel, it means that the oil enters the cylinder and is subject to burning with the fuel. The additives in some regular crankcase oils do not burn completely. They sometimes leave a residue that fouls the spark plugs and clogs the exhaust ports. The special additives are used so that this does not happen. Many of the oils containing these additives are sold by the engine dealer. Specially blended two-cycle oil is readily available at any maintenance supply store.

Consider oil viscosity grade. Viscosity is the resistance to flow. It is rated in SAE numbers as "SAE 30". Manufacturers recommend different viscosity grades for different temperatures.

Note that there are single viscosity-grade oils, such as "SAE 30", and multi-viscosity grade oils, such as "SAE 1OW-30".

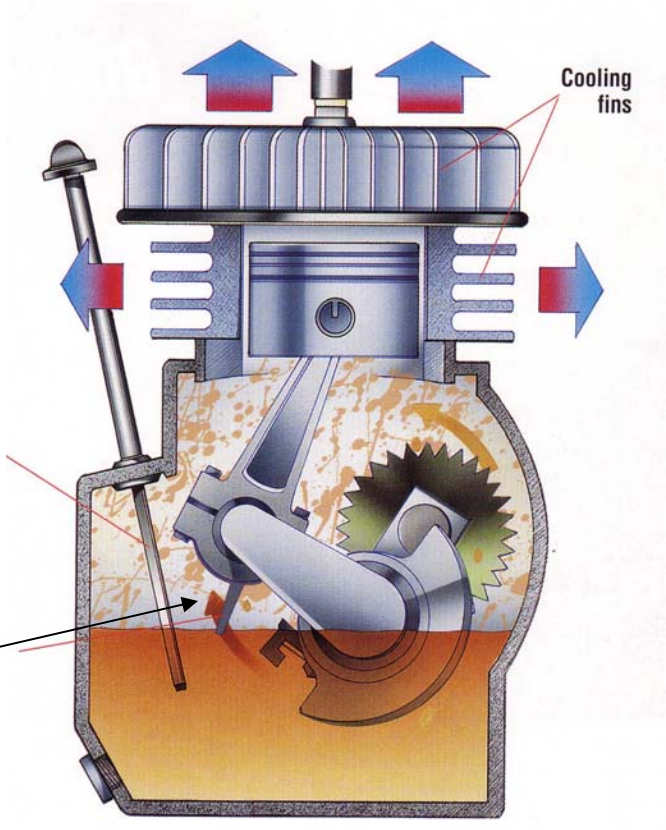
Most 2-cycle, and many 4-cycle, engine manufacturers recommend a single viscosity grade oil - usually SAE 30.

4-Stroke Lubrication:
We all know what happens to a door hinge that is not oiled. It becomes squeaky and stiff from lack of lubrication. If your small engine did not have oil in it, the same thing would happen, except worse. The engine would probably **seize up**, or stick, from the lack of oil. This is why lubrication of all moving parts is so important.

There are two common types of lubrication: Splash and Oil-Pump. In Splash Lubrication, there are two styles: the oil dipper, and the oil slinger.

1. Connecting Rod Dipper

   All four-stroke engines contain an oil reservoir in the bottom of the crankcase. One design has a dipper at the base of the connecting rod that dips into the oil reservoir with each stroke. As the connecting rod moves up, oil clinging to the dipper is thrown up and out toward the crankcase walls. The direction of the oil throw is controlled by the shape of the dipper. The oil is vaporized in the upper part of the crankcase and is carried in vaporous form into the engine parts. Both vapor and the oil flow along the crankcase walls carry oil into the crankshaft and camshaft bearing holders. The piston rings seal the crankcase so that oily vapor does not get into the combustion chamber.



The Oil Dipper: This little "paddle" splashes the oil around the crankcase.

2. Oil Slinger

Oil slingers are usually driven by the camshaft but can be mounted on any other shaft that is driven by the crankshaft. They may be cylindrical or plate shaped, and usually have projections or dished shapes which scoop up the oil when they dip into it and throw it against the crankcase walls as they rotate. As in the connecting rod dipper types, part of the oil entering the atmosphere above the oil reservoir is vaporized and carried by the atmosphere to the working parts. In addition, the oil flows down the crankcase walls, entering the oil crankshaft and camshaft holders, and lubricating these parts. Excess oil flows back down to the oil reservoir.

There are three different types of oil pumps in small engines. They are:

1) Positive Displacement Gear Pump
2) Rotor Oil Pump
3) Barrel-Plunger Pump

These pumps push oil through passages in the crankcase walls to points where lubrication is needed most. Oil is also sprayed into the crankcase.

Engine position is important in 4-stroke engines. The oil lubricator must be able to reach the oil to work properly. An angle greater than 15° is not recommended.

Different engines operate at different angles, so it is a good idea to check your operator's manual for the maximum operating angle.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Know the basics of gaskets.
- Select the right oil.
- Understand lubrication

Smooth Running 1: Oil change

In this activity students will:

- Make a critical analysis of the condition of the crankcase oil
- Drain and properly dispose of the old oil.
- Correctly replace the drain plug, and oil filter (optional)
- Refill the oil to the correct level

Tools required

- Appropriate manufactures recommended oil
- Socket set
- Clean cloth
- Funnel
- Oil drain pan
- Oil filter wrench (optional)

Inspection

- Clean around the top of the oil filler cap (located at the base of the engine)
- If the engine is equipped with a dipstick check the level of the oil and the colour
- Note the oil should be checked when the engine is cold. If the engine has been run allow 15 to 20 minutes to allow the oil to settle in the crankcase.
- The oil should be golden amber colour and be smooth to the touch.
- Oil that is old is a deep black colour and has a gritty feel to it.

Oil Change

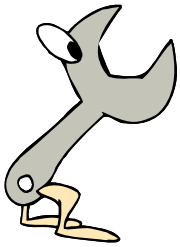
- Place the engine on an elevated bench
- Locate and remove the oil plug – usually on the underside of the engine (the plug may be covered by dirt and debris)
- Have the drain pan ready – warning - be sure the engine is cool - warm oil flows better but can also cause serious burns.
- You may notice that very little oil comes out, if this is the case it may be necessary to open the filler cap to relieve the internal vacuum.
- If your engine has a filter, remove it now – the filter may have oil in it so unscrew it over the oil pan.
- When the oil has finished draining:
- Place the old oil in a receptacle that can be safely disposed of, do not dump the oil down the storm drains or sewers.
- Replace the drain plug, taking care not to cross thread the bolt.
- Dip your finger or a clean cloth in the new oil and rub the seal on the oil filter. This will ensure a good seal and prevent leakage. (If your engine has a filter.)
- Pour the new oil in the engine, stopping frequently to check the oil level. Too much oil is almost as bad for an engine as not enough.
- Replace the filler cap and test start your engine.

1) Compare the oil used in the gasoline for a 2-cycle engine with the crankcase oil used in a 4-cycle engine. Does it differ in looks, smell, or feel?

2) Make a calendar for times when the oil should be changed on your 4-cycle engine and post it near where it is stored.

3) Change the oil in your engine and compare it with "new" oil in looks, smell and feel.

4) After removing the drain plug, check it to see if it is magnetic. Does it attract metallic particles?



Smooth Running Program Reports

- Have members complete the "Oil Change Calendar" on page 5.

Tips Quality Equation

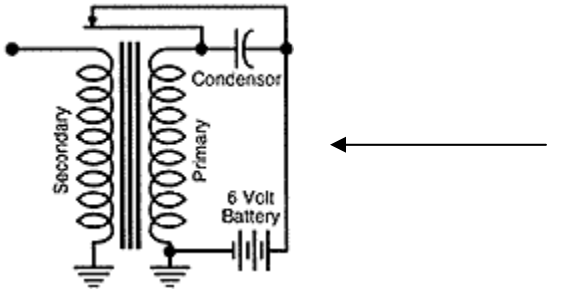
To develop a pride in quality workmanship, encourage members to persevere and repair the motor properly and emphasize how important ongoing maintenance is to ensure their hard work pays off for a long time.

How Small Engines Work – Ignition system

Science Background for Leaders

You know that a spark from the spark plug ignites the fuel air mixture in the combustion chamber of a small engine. But do you know where the spark comes from? This section presents the ignition system and all its parts, how it works, and how to adjust it for proper operation.

There are two common type ignition systems - magneto and battery. The basic difference between the two systems is that the **battery type gets its primary electric current from a battery** and the **magneto gets its primary current from a magnetic rotor**. Most small engines use the magneto type. Cars and tractors usually use the battery type.



A Schematic diagram of battery type ignition system, showing the primary (the low voltage side) and the secondary (The high voltage side)

There are several vital parts to the ignition system. The word "ignition" comes from ignite, "to cause fire".

A magnetic field exists from the north pole to the south pole of a magnet and between the opposite poles of two magnets. It matters little whether the wire is moved past the wire, or whether the magnetic field is built up and collapsed around the wire, the current flows just the same.

In most **magnetos** a permanent magnet is rotated in a coil core or moved by a coil core so that a fluctuating magnetic field is induced into the core. The fluctuating magnetic field induces a current in the primary coil wire. When the north pole of the rotating permanent magnet, as shown in the sketch, is opposite the right hand of the "U" shaped coil core it makes a temporary south pole out of this part of the coil core. The south pole of the rotating magnet makes a north pole out of the left side of the "U" shaped coil core. This causes the total coil core to be temporarily magnetized with poles as described. When the permanent rotating magnet turns so that its north pole is opposite the left side of the "U" shaped coil, it changes this part of the coil core from a temporary north pole to a temporary south pole. This switch around causes the entire core coil to change its magnetic field. In this switching process the first described magnetic field completely diminishes and a reversed field appears. Now, remember if we collapse a

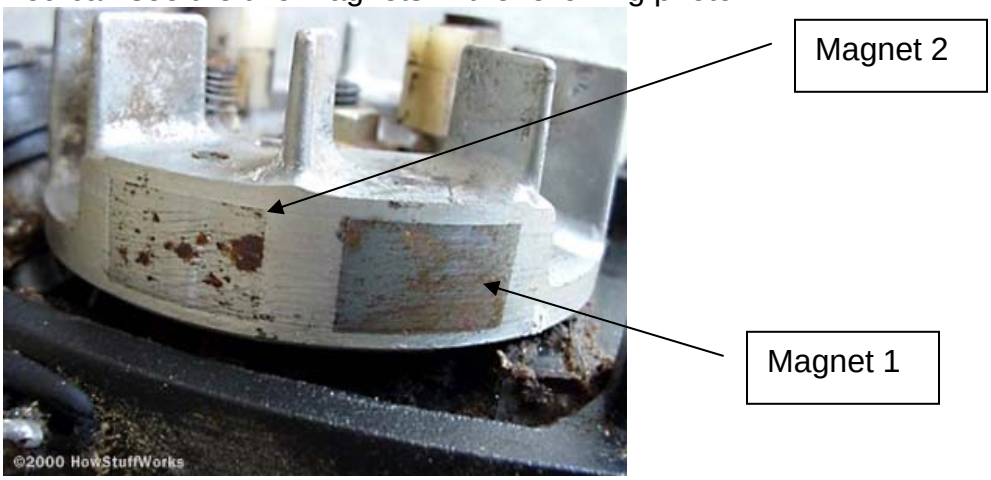
magnetic field through a wire coil, current will be generated in the wire coil. Thus, as the permanent magnet turns, the magnetic field is constantly reversing itself thus generating a current in the primary wire.

Types of Ignition Systems

A magneto consists of five parts:

- An armature. In the above magneto, the armature is shaped like a capital "U". The two ends of the U point toward the flywheel.
- A primary coil of perhaps 200 turns of thick wire wrapped around one leg of the U
- A secondary coil of perhaps 20,000 turns of very thin wire wrapped around the primary coil
- A simple electronic control unit that commonly goes by the name "electronic ignition" (or a set of breaker points and a capacitor)
- A pair of strong permanent magnets embedded in the engine's flywheel.

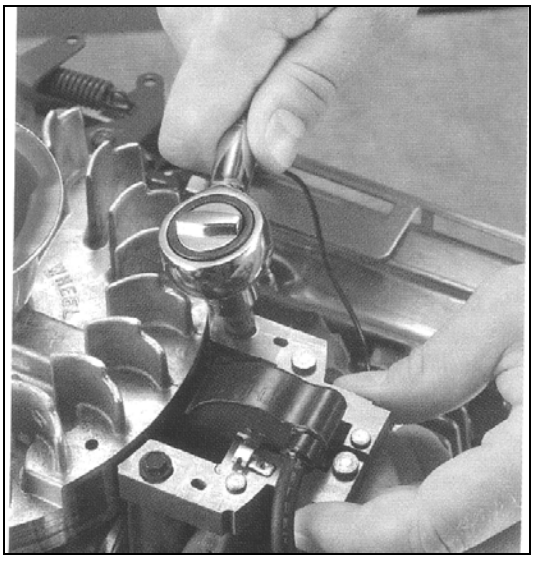
You can see the two magnets in the following photo:



When the magnets fly past the U-shaped armature, they induce a magnetic field in the armature. This field induces some small amount of current in the primary and secondary coil. What we need, however, is extremely high voltage. Therefore, as the magnetic field in the armature reaches its maximum, a switch in the electronic control unit opens. This switch breaks the flow of current through the primary coil and causes a voltage spike (of perhaps 200 volts). The secondary coil, having 100 times more turns than the primary coil, amplifies this voltage to approximately 20,000 volts, and this voltage feeds to the spark plug.

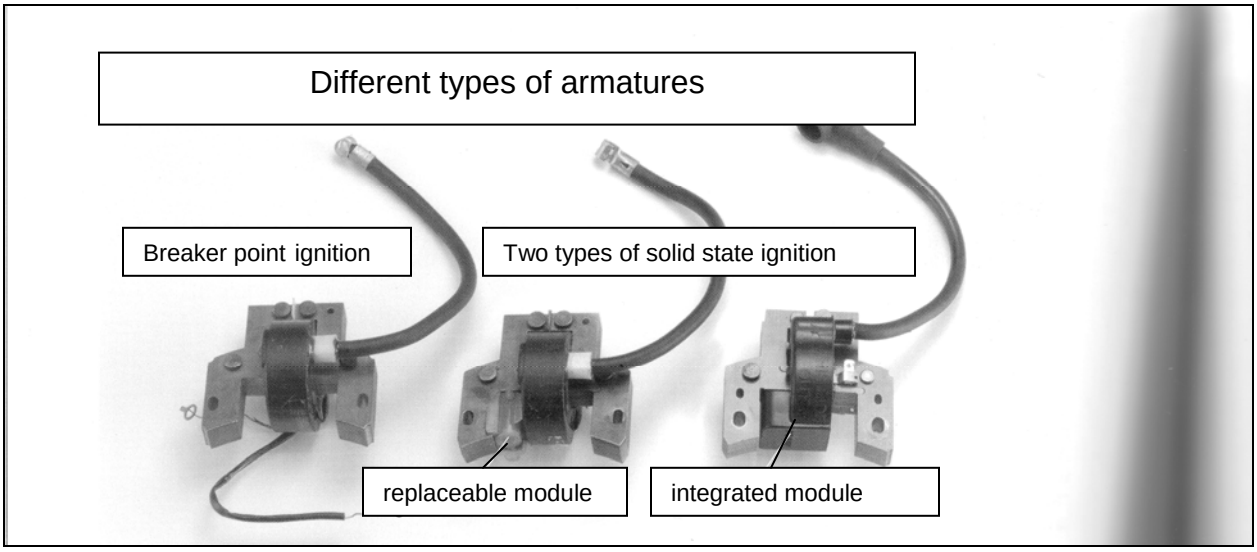
Magnetos are fabricated in different ways on different engines. Some will have permanent magnets included in the flywheel with the coil mounted on a stationary plate inside the flywheel. Others may have permanent magnets built into the flywheel with the coil stationary on the outside of the flywheel.

Other magnetos may have the permanent magnets mounted on the crankshaft and the coil and coil core mounted on a face plate. On all these units it is important to have the clearance between the permanent magnet and the coil core (called the **air gap**) just as close as can be without having metal to metal contact. The closer these pieces are together the stronger the magnetic field will be between them. All these units, regardless of the relative positions of the magnets and coils, generate ignition current in the same way. The permanent magnets moving past the coil core cause a changing magnetic field in the coil core which induces a current magneto in the primary coil. This current flows as long as the breaker points are closed. At the instant the current is greatest in the primary wiring of the coil the breaker points are opened. The resulting collapse of the magnetic field around the primary wiring induces a very high voltage current in the secondary wiring in the coil. The voltage of this current is high enough to jump the electrode gap in the spark plug.



Armature is attached to the block next to the flywheel

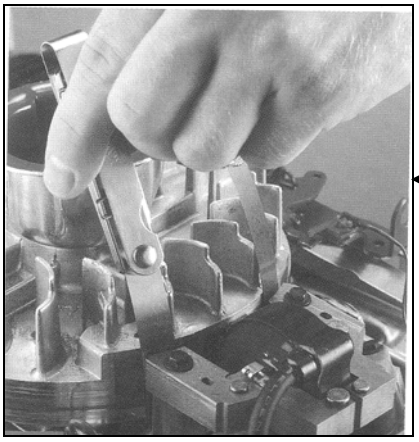
Prior to 1982 small engines had a set of breaker points like the ones described above. These points are moving mechanical systems that were frequently the cause of ignition failure. These points have been replaced by solid-state electronics. A device called a transistor takes the place of the old "points" system. Current is still fed to the spark plugs at the precise instant but by using a solid state system it is much more reliable.



The armature, which contain the solid-state circuitry is bolted onto the frame of the engine and is set a precise distance away from the flywheel. As stated earlier as the magnets on the flywheel pass the armature, the transistor allows the 20,000 volts into the spark plug and as a result the plug fires. However, in order for this to happen the armature must be a precise distance from the flywheel. These distances are 0.006" to 0.010" or 0.010" to 0.014" depending on the type of ignition system you have.

Feeler Gauge

In order to set the correct distance from the armature to the flywheel it is necessary to use a precision measuring device called a "Feeler Gauge". A feeler gauge is a series of "slips" of metal that are of vary thicknesses. They resemble painting samples that decorators use only much thinner. Each slip of metal has the thickness stamped on it. Simply insert the slip of metal into the gap when the metal fits snugly in the gap you read the measurement.



Using a feeler gauge to adjust the armature

The condenser connected across the breaker points offers a path for the primary current flow during the first instant the points begin to separate. The current flows into the condenser instead of arcing across the breaker points. This instant storage of the primary current permits a quick collapse of the magnetic field around the primary wiring which is essential for a high voltage current to be induced in the secondary wiring. Immediately after the spark takes place at the spark plug the breaker points close and the current stored in the condenser discharges back into the primary wiring of the coil.

The spark that ignites the fuel must take place at a precise time if the engine is to run smoothly and develop expected power. After studying how the magneto produces the spark, it is obvious the relative positions of the cam that breaks the points, (or set off the transistor – in a solid state ignition system), the coil, and the permanent magnets, determine when the spark will occur. This is called the flash point.

This flash point must be when the piston is a precise distance from the top of the cylinder on the compression stroke. The manufacturer determines this position and places a timing mark that establishes the relative position of all the parts. When working on engines, be sure to locate this timing mark. This timing mark is sometimes called TDC or when the piston is at Top Dead Centre.

If we suddenly stopped the current flow in the **primary wire**, the magnetic field around the primary wire would collapse. The collapsing magnetic field moving past the **secondary wire** would induce a current in the secondary wiring. You will also remember from your study of electricity that since there are many more wires in the secondary coil, the voltage of this current will be much higher than the voltage of the primary current. The secondary coil is connected to the spark plug by the spark plug wire. When this high voltage current gets to the spark plug, it jumps the gap between the center and ground electrodes causing a spark that ignites the fuel. The generation and precise timing of this spark is the sole purpose of the ignition system.

The spark is timed precisely by the **breaker cam** that opens the **breaker points** which collapses the magnetic field around the primary coil winding. The timing on many small engines is fixed in the engine design and assembly. On some engines small timing changes can be made by rotating the coil and coil core or changing the breaker cam. To make hard starting easier, some engines use a device known as an impulse starter. This is a simple spring latch that retards the spark at cranking speeds.

The **condenser** serves as a temporary storage place for the primary current to prevent the primary current from arcing across the breaker points as they are separated.

Why is the coil core made up of thin pieces of metal with insulation layers between? To prevent small currents being formed in the core that would cause overheating and loss of efficiency.

Spark Plugs

The sole purpose of the spark plug is to furnish a spark that is adequate to ignite the fuel mixture. All spark plugs look very much alike, but close examination will reveal they can be different in several places. Each of these differences are brought on by different engine requirements.

The **threaded diameter** is furnished in the following sizes:

- 10 millimeters
- 14 millimeters
- 18 millimeters
- 7/8 inch
- 1/2 inch

Most small engines use the 14 millimeter size. It is important that the plug extend into the cylinder the amount designed by the manufacturer. So, be sure to select a plug with this needed dimension. Plugs are available in reach dimensions of 9.5 mm, 22 mm, 1.3 mm, and 19 mm (3/8", 7/8", 1/2", and 3/4").

The spark plug may seem like a common part and as such its importance is sometimes over looked. The tolerances on any engine are exceedingly fine. The spark plug sits at the top of the block, if the plug is too long it is conceivable that the piston may hit the spark plug. If the plug is too short it may be too far away from the air/fuel mixture to ensure proper ignition. It is also essential to get the right thread on the spark plug, if the threads on the plug do not match those of the block it can cause leaks or even damage to the block.

When the spark plug is tightened into the engine, the spark plug gasket should be crushed enough to form an airtight seal. Care should be observed though against tightening too tight and cracking the porcelain insulator part of the plug.

If you are using a foot long spark plug wrench, then apply about 25 pounds pressure on the end of it to properly seal the spark plug. The spark plug reach should be sufficient so that the plug is even with the inside of engine cylinder as shown. Spark gap setting is an important part of the effectiveness of the spark plug. Gap setting of .64 mm to .76 mm. (.025" to .030") is common for most small engines. Continued arcing of the spark plug electrodes will burn away some of the electrodes. This causes the spark gap to get wider which could cause hard starting and engine miss under load. Therefore the spark gap should be reset periodically to the recommended spacing as previously indicated. This adjustment is made by bending the ground electrode toward the center electrode. For best results always make the spark gap measurement with a spark plug gauge.

There may be other special design features of spark plugs such as the one frequently used in two-cycle engines. The fuel used in a two-cycle engine has more carbon in it than regular gasoline. You will notice the ground electrode does not completely cover the end of the center electrode in this spark plug. This design is less likely to bridge over with carbon residues.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Understand how magnetos work.
- Understand how spark plugs work.

Smooth Running 1: Ignition test and replacement

Objectives:
Members will

- Be able to demonstrate if their ignition system is providing a suitable "spark"
- Successfully remove the armature
- Successfully replace the new armature

Tools Required:

- Socket set
- Pliers
- Set of alligator clips
- Feeler gauge.
- Spark tester (optional)

Spark plug inspection

- Drain the gas from the engine – gasoline is highly combustible and should not be around even in the smallest quantities when dealing with ignition systems.
- Remove the spark plug, using a spark plug wrench.
- The end of the spark plug should be a shiny silver colour.
- If the end of the spark plug is black it should be cleaned with a small file or emery cloth
- Check the gap on the spark plug with the feeler gauge; be sure it is within manufactures specifications. Use pliers or a small hammer to adjust the gap.

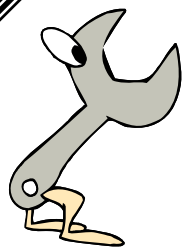
Spark inspection

- Some small engines will have a stop switch (sometimes called a kill switch) connected to the armature. This switch allows the user to shut off the motor by "grounding out" the armature. This switch needs to be disconnected or placed in the run position.
- Firmly connect the top of the spark plug to the plug wire.

- Attach the alligator clip to the thread of the plug.
- Connect the other end of the alligator clip to a bolt head or another source of ground.
- Note: A spark tester can be used in much the same way, just follow the manufacture's instructions
- Dim the lights
- Gently pull on the starter cord or allow the electric to "crank" a few times (if your engine is equipped with an electric starter)
- You should see a bright spark jump across the end of the spark plug.
- Warning the spark that is jumping across the spark plug is in excess of 15,000 volts; it is not enough to cause serious injury but may result in a powerful shock or a burn.

Armature replacement:

- If the spark has been cleaned and gapped and there is still no spark then it is possible that the armature has failed and will have to be replaced.
- Remove the top cowling from the engine, thus exposing the flywheel.
- The armature is held onto the engine housing with two bolts.
- Remove the bolts and take off the armature
- Reinstall the new armature using the reverse procedure. Note: tighten the bolts only finger tight.
- Using the feeler gauge, adjust the armature to the manufacture's recommended distance from the flywheel.
- Reconnect to the spark plug to the lead and test to see if you have a spark.



Smooth Running Program Reports

- Have members complete the "Ignition Repair List" on page 5.

Q Tips
Quality Equation

To "spark" member's internal motivation, be generous with praise and understanding of their frustrations. An adult's encouragement believing "that you can do it" can go a long way to supporting a 4-H member's growth.

How Small Engines Work – Crankcase Breathers

Science Background for Leaders

Four-stroke engines have a "breather vent" in the crankcase.

Crankcase breathers serve four purposes:

- Avoid a build-up of excessive pressure in the crankcase.
- Allow for removal of harmful gases and vapors from the crankcase.
- Maintain a partial vacuum - or a slight pressure - in the crankcase.
- Keep out dust and dirt.

Two-cycle engine crankcases are not vented because the fuel and oil enter the combustion chamber through the crankcase. The crankcase is sealed and operates under pressure.

Crankcase breathers should be cleaned at least once each year. Servicing the breather consists of cleaning the filter element and checking the breather valve for proper operation.

Types of Crankcase Breathers and How They Work

The breather is usually located in the valve-tappet access-well or in the valve-tappet access-well cover.

Here's how the crankcase breather prevents excessive pressure build-up in the crankcase. During combustion a certain amount of "blow-by" from the combustion chamber passes by the piston rings into the crankcase. If your engine had no breather, this pressure would build up to the point where oil seals and gaskets would be ruptured and oil leaks would result. Consequently, if the breather does not operate properly, or if it becomes clogged, the results are the same as they would be with the engine having no breather. The crankcase breather valve relieves the excessive pressure by providing an outlet for air to escape when the pressure in the crankcase becomes greater than that of outside air pressure.

Harmful gases and vapors are removed from the crankcase by the same action. These gases and vapors get into the crankcase as a result of blow-by past the piston. This in turn causes corrosion of engine parts and loss of lubricating qualities in the oil.

On some 4-cycle engines the breather provides a partial vacuum in the crankcase. The valve allows the gases to escape from the crankcase, but a lesser amount of air is allowed to enter. This process is done by two different methods:

i) some valves are designed so as not to close completely, and
ii) some close but have a small opening in the valve to allow some air to enter.

As a result, a partial vacuum (from 1/7 kPa to 3.4 kPa (.5 in Hg to 1 in Hg) or only a slight pressure is maintained in the crankcase. 3.4 kPa = 1 in Hg. This low or negative pressure helps prevent oil leaks through the oil seals and gaskets.

(a) As the piston moves down, pressure builds up in the crankcase. This pressure is a result of both the downward motion of the piston and the "blow-by". The valve in the crankcase breather opens and allows air to escape. This reduces the pressure and gets rid of harmful gases and vapors.
(b) As the piston moves upward, pressure is reduced in the crankcase. The valve in the crankcase breather closes, thus allowing little or no air to enter. This closure maintains a partial vacuum or slight pressure in the crankcase.

The metal reed valve is opened by pressure in the crankcase, and it is partially closed by spring tension. (Neither valve closes completely.) This action controls the amount of air that enters the crankcase.

The steel ball-check and floating disk valves float freely. They are opened by pressure in the crankcase, and partially closed by gravity or atmospheric pressure.

Air from the crankcase may be vented either to the outside air or to the carburetor. If the breather is vented to the atmosphere, a filter is necessary. Its job is to remove dust and dirt from the air entering the crankcase. It is a part of the crankcase breather. Filters are made of metal maze, animal hair, or polyurethane.

Importance of Proper Servicing

If the breather becomes clogged, excessive pressure, or vacuum, builds up in the crankcase; oil seals and gaskets become ruptured; and oil leaks develop. Failure to clean the filter regularly may cause this condition.

If the inlet passage becomes clogged, air can get out but not in. Too much negative pressure (vacuum) will develop and dirt will be drawn in through the oil seals. Gaskets will have a tendency to be drawn into the engine.

If oil leaks out through the breather, it is a good sign of a clogged breather valve, or worn or damaged parts. It may be an indication, however, of improper breather assembly, engine running too fast, operating the engine at too much of an angle, worn piston ring, or breather installed up-side-down.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Understand basics of crankcase breathers.

Smooth Running 1:

Objectives:
Students will be able to:

- Demonstrate where the crankcase breather is
- Make a determination as to whether the crankcase breather is working up to manufacturers specifications.
- Demonstrate the removal and replacement of the crankcase cover gasket

Tools Required

- Socket set
- Torque wrench
- Feeler gauge
- Wooden or plastic scrapper
- Emery cloth
- Pencil and thin cardboard
- Materials used for draining oil – see activity 1
- Solvent (optional)

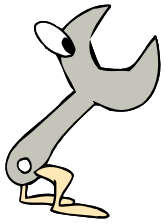
The crankcase breather

- Locate the crankcase breather, it is small metal box and is usually located near the valve chamber.
- Note: it may be necessary to remove the muffler to get at the breather.
- Remove the breather from the engine block.
- Use a feeler gauge to test the gap between the fiber valve and the breather body. If it is more than 0.045", then it must be replaced.
- Note: Do not try to adjust the breather, they must be replaced.
- Note: when the new breather is attached it will also need a new gasket.

The crankcase cover

- Depending on the type of engine the crankcase cover will be on the side or bottom of the engine. The cover hides the bottom of the piston and crankshaft.
- Drain the oil
- Clean the area thoroughly- any particles on the engine may find their way in the engine.
- Make a sketch of the outline on the cover, noting the location of the bolts.
- Remove the bolts in a criss-cross fashion.
- Place the bolts on your sketch to make sure the same bolts go back in the same spots.
- Working from side to side leaver up the crankcase cover.
- Remove as much of the gasket as possible.
- Using the scrapper remove the rest of the gasket material
- If any trace of the gasket remains use emery cloth or solvent (optional)
- Check the crankcase for any foreign objects
- Set the new gasket on the cleaned crankcase cover

- Replace the bolts in the same position that they came out.
- Work in the same criss-cross pattern to tighten the bolts, use a torque wrench to tighten to manufacture's specification
- Refill crankcase with oil – see activity A
- Test-start the engine and watch for any leaks.



Smooth Running Program Reports

- Have members complete the "Crankcase Breather Repair List" on page 6.

Tips Quality Equation

The more ways that we teach, the more people that we reach. Throughout this project, you will find a variety of teaching techniques – reading, writing, drawing, hands-on, investigative, individual and group work, etc. People learn best in a number of different ways. Using a variety of teaching methods helps to ensure everyone understands the message.

How Small Engines Work – Fuel System

Science Background for Leaders

This section covers engine fuel, fuel tanks, air cleaners and carburetors, all parts of the system your small engine uses to keep itself running. Theories of operation and disassembly will be discussed in each case.

Fuel Selection

Gasoline is ideally suited for spark-ignition engines for several reasons. The more important of these are the following:

- Gasoline vaporizes readily.
  Petroleum products will not burn when in a liquid state. They must first be evaporated and mixed with air. Since gasoline vaporizes readily, it helps assure easy starting and complete combustion during operation.
- Gasoline burns at a relatively moderate speed.
  The fuel in the combustion chamber must not explode. It must burn at a smooth, even rate. Gasoline does this, thus preventing knock.
- Gasoline comes in different octane ratings.
  Different engine designs require gasolines with different octane ratings. The higher the engine compression ratio, the higher the octane rating required for smooth, even burning.

You might think that anyone should be able to put gasoline in an engine properly. There are several facts, however, about selecting fuels, about preparing them for 2-cycle engines, and about the method you use when filling the tank that are important for you to know.

Selecting the Fuel

The octane rating (anti-knock quality) of regular grade gasoline (90-92 octane) is recommended by most manufacturers. No-lead or lead-free gasolines are satisfactory, but many cost more. They actually result in cleaner burning. The compression ratio is usually 6 to 1, or 7 to 1. If you use gasoline with too low an octane number for the compression ratio of your engine the fuel will burn unevenly and detonate, or "knock". This is usually not a problem with small engines. The use of highly leaded gasoline should be avoided. It causes deposits on the valves, spark plugs and in the cylinder head.

Detonation will happen when the fuel burns unevenly. Part of the fuel charge in the combustion chamber is ignited by the spark plug. The unburned portion of the fuel mixture becomes compressed until its temperature reaches the point of self-ignition - as

in a diesel engine. This causes knock, or detonation. Detonation causes a hammering force on the piston rather than a uniform pushing force.

Detonation will cause your engine to lose power, and the engine may even suffer serious piston damage. Your engine will also operate at a higher temperature. Prolonged operation at excessive temperatures will cause valve burning.

Provisions for easy starting are also built into fuels by producers of gasoline. It is fitted to the type of weather in the area in which it is sold. In summer, oil companies blend their gasoline so **volatility** (its tendency to evaporate) is low. Therefore, if you use summer gasoline after the weather turns cold, you may have trouble starting your engine because of its low volatility.

Fuel tanks come in various shapes and sizes. They are molded to fit the contour of the engine. The gas cap is usually easily reached for refilling the tank. Fuel tanks are made from aluminum or hi-impact plastic.

The fuel tank should be cleaned outside and inside before the engine is reassembled. Use a solvent, and dry the tank thoroughly. The fuel line should be removed and cleaned as well. Set the fuel line in a container where it will not be punctured, dented, or damaged.

Air cleaners should be removed and serviced when overhauling an engine. Use the proper servicing procedure for the type of air cleaner you have. Set all the parts of the air cleaner in a container so they cannot get dusty.

Carburetor and Fuel System

The **carburet**or is the part of the small engine where air and fuel are mixed together before they travel through the intake valve to the cylinder. The carburetor uses a fast air flow and a **venturi** to make fuel into a vapour that will explode easily.

Common small engine carburetor

The **fuel tank** is where the gasoline is stored. It is far enough away from the cylinder to stay cool. A hose or pipe carries the fuel to the carburetor, where a **valve** lets fuel into the carburetor as fuel is needed. The fuel is sucked through a tube called a **fuel jet** into the stream of air.

The speed of the small engine is controlled by the **throttle**, which controls the amount of fuel-air mixture allowed to enter the cylinder.

The amount of air allowed to enter the carburetor is controlled by the **choke**. As the name says, it "chokes" the amount of air, making more fuel and less air go into the cylinder. A cold engine needs more fuel to start. This is why the choke must be on to start a cold engine.

There are some adjustments which can be made to a carburetor. The first is the **main fuel adjusting needle**. This adjustment changes the amount of fuel allowed to enter the fuel jet. The idle speed, or slowest speed, of the engine is controlled by an **idle adjusting needle**, which only lets in so much fuel when the throttle is closed in its idle position).

Types of Carburetors and How They Work

There are three types of carburetors used on small engines; depending on how fuel is supplied from the tank to the fuel chamber in the carburetor. They are:

A) Float-type
B) Suction-Lift type
C) Diaphragm-type

Each operates on the same basic principles, but when you first look at them, you may think they are quite different.

A. Float-type carburetor

Float-type carburetors are so called because the fuel level in the fuel chamber is maintained by a float-controlled valve. There is however, more to the float carburetor than this. Included are additional features which provide for adjustment and regulation of the fuel-air ratio to meet different operating conditions.

When a sudden load or acceleration is demanded of the engine, a richer mixture (more fuel-air ratio) is required. The governor opens the throttle valve and air moves past the nozzle much faster, thus picking up additional fuel, thus supplying a richer fuel mixture to the engine.

Without this feature an adequate flow of fuel would not be maintained from the float chamber and the engine would miss during acceleration.

A small opening (orifice) in the air bleed restricts the air and prevents the mixture from becoming too lean.

The high-speed valve automatically provides a fuel-air ratio adjustment after acceleration. If the heavy load continues, the fuel-air mixture need not continue to be so rich. With the acceleration well empty, the air passes through the air bleed opening into

the accelerating well and out through the nozzle along with the regular fuel supply, thus reducing the richness of the mixture.

When idling, the throttle valve is closed. Air flow through the venturi is not sufficient to reduce the pressure enough to draw fuel from the float chamber. An additional fuel outlet is provided, past the throttle valve (between the throttle valve and the engine). This outlet supplies fuel (at the proper mixture) to the engine for idling.

As the throttle valve is opened, the lower discharge port, also becomes exposed to low pressure in the intake manifold. Through it an additional supply of fuel-air mixture is delivered to the engine to prevent a lean mixture when the throttle is slightly open. Opening the throttle further causes the main fuel nozzle to supply fuel by the venturi action. It continues to do so on an increasing scale as the throttle valve opens.

When you choke your engine, you close the choke valve so that the air supply is almost cut off. What air is supplied passes either the edges of the choke valve or through a special opening provided through the choke valve. With most of the air supply cut off, a greater vacuum develops in the manifold, thus causing an increasing amount of fuel to be supplied through the fuel nozzle, and a richer fuel-air mixture.

Some manually operated choke valves are designed to latch in fully open position, and some are designed to latch in the fully-closed position. Others have intermediate latch positions. Some are spring loaded to open, and you have to hold them closed for starting.

Some automatic chokes have variable positions depending on the temperature of the engine. Most automatic chokes use coil springs. Metal expands when heated and contracts when cooled. The coil spring lengthens when heated and shortens when cooled, thereby giving the rotating motion needed to open and close the choke valve.

It is more and more common to find small engines with no choke at all, but rather a primer instead. A primer is a type of pump with which you can actually pump extra gasoline into the carburetor air intake. They are used on most all multi-position engines and some vertical and horizontal position engines.

Some have a "tickler" or a device for tripping the float which allows more fuel to go through the needle valve.

B. Suction-lift carburetor

The suction-lift carburetor is a second type. It is usually mounted on top of the fuel tank. It is used primarily on inexpensive 4-cycle engines. Vacuum from the engine intake stroke - downward motion of the piston, 4-cycle engine, or upward motion of the piston, 2-cycle engine - causes low pressure in the venturi. Atmospheric pressure forces fuel up through the tube into the low pressure area of the venturi and then into the engine.

The horsepower is limited on engines using this type of simple carburetor. This is because the suction lift is quite limited. Fuel flow to the carburetor varies with the

amount of fuel in the tank. For engines of 370 W to 2240 W (2 hp to 3 hp), however, it works satisfactorily.

One suction-lift type carburetor is designed with a means for choking, running and stopping - all in one control valve.

Larger sizes of suction-lift carburetors include a diaphragm fuel pump which fills an auxiliary fuel reservoir. With this design very little fuel "lift" is required to draw gasoline into the venturi. Since less suction is required, the venturi can be made larger, thus permitting a greater volume of fuel-air mixture to flow into the engine with a consequent increase in horsepower. Also, the fuel flow to the carburetor does not vary with different fuel levels in the tank.

Here is how the diaphragm pump works.

1) Fuel is drawn from the tank into the pump chamber.
   The spring side of the diaphragm is connected to the intake manifold. Suction from the engine pulls the diaphragm toward the spring and compresses it. This movement creates low pressure on the opposite side of the diaphragm, which is the fuel side of the pump chamber. Fuel from the fuel tank is forced into the chamber by atmospheric pressure. The pressure of the fuel opens the inlet flapper valve and closes the outlet flapper valve. Fuel enters the pump chamber.
2) Fuel is then forced into the carburetor (auxiliary) reservoir.
   At the end of the intake stroke the vacuum is relieved from behind the diaphragm. Spring tension returns the diaphragm to its original position and forces the fuel into the auxiliary reservoir.
3) Fuel is forced into the (venturi) carburetor throat from the reservoir in the same manner as that from the suction-lift carburetor.

C. Diaphragm-type carburetor

The diaphragm-type carburetor is a third kind. It uses a spring-loaded diaphragm for regulating the fuel flow into the carburetor fuel chamber.

The diaphragm serves the same purpose as the float in the float type carburetor, but the use of the diaphragm allows engines to be operated at any angle. This feature makes this type of carburetor adaptable to multi-position engines, but they are also used on vertical and horizontal position engines. Do not confuse this with the diaphragm pump just described. Many diaphragm carburetors, however, also use a diaphragm pump in addition to the valve-activating diaphragm.

It is especially adaptable to 2-cycle engines which provide for activating the diaphragm from low pressure in the crankcase.

Here is how it works. As the piston moves (down, 4-cycle engine, or up, 2-cycle engine), suction is created in the venturi section of the carburetor. Atmospheric pressure forces the diaphragm up. The fuel valve opens. Fuel enters the diaphragm chamber and flows on through into the venturi section and to the engine cylinder. When the piston moves in the opposite direction and no suction is created, the diaphragm valve closes and the diaphragm chamber and the fuel passageways remain full of fuel - ready for the next intake stroke. All this happens very rapidly and a constant supply of fuel is available to the engine.

There are certain amounts of vapourized fuel that must mix with air to keep the engine running smoothly under specific conditions.

The following are examples of ideal fuel-air ratios for different operating conditions.

Operating condition	Ratio of 1. air required per 1. of fuel
Cold starting	1:7
Accelerating	1:9
Idling	1:11
Part throttle - loaded	1:15
Full throttle – loaded	1:13.5

Here's an example of how much air an engine uses:
- The engine is idling, 3 litres of fuel have been used
fuel-air ratio = 1:11

Fuel	Air
1	11
3	*X*

Cross multiply:
X x 1 = 3 x 11
X = 33

33 litres of oil will be used.

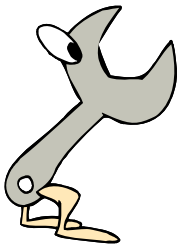
Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Understand the importance of fuel selection.
- Know about the different types of carburetors.

Smooth Running 1: Carburetors

Clean and adjust the carburetor for optimum performance.



Smooth Running Program Reports

- Have members complete "Carburetor Countdown" on page 6.

Q Tips
Quality Equation

The project is a means to an end. The 4-H program is about youth development. Use the project activities as opportunities to build members' teamwork abilities, self-confidence and esteem and responsible, quality work ethic while they learn new skills.

How Small Engines Work – Cooling System & Speed Control

Science Background for Leaders

The cooling system is a very necessary part of the small engine. An engine allowed to overheat could be damaged beyond repair, because overheated metals will crack or warp. For this reason, small engines are designed to cool themselves.

Air cooled engines use **fins** to increase the surface area of the hot areas - mainly around the combustion chamber, or cylinder. Air is forced over the fins by the **flywheel blower fan**. The flywheel blower fan usually consists of a series of vanes. **Shrouds** are used to direct air through the cylinder fins to assist the cooling process. Shrouds should **never** be removed and not replaced before using the engine.

Vanes for directing air on the flywheel

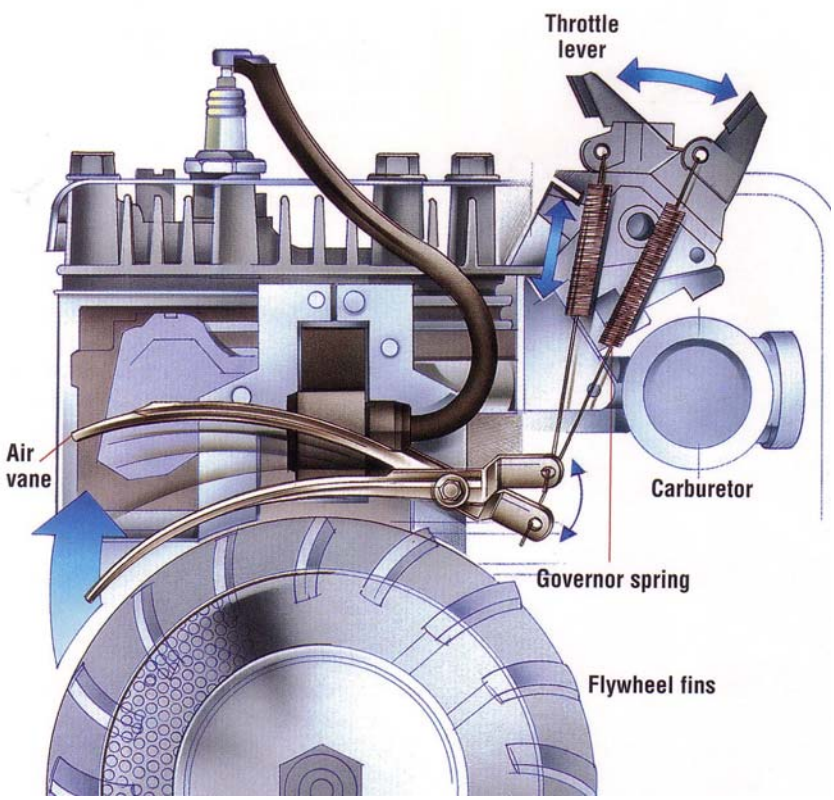
Shrouds/baffles are usually the first thing removed when overhauling an engine, since they cover most of it. Remember to note where all bolts and pieces fit together to make reassembly easier. (If you don't think you'll remember, draw a diagram of the parts.)

Throttles, ground wires, etc. may be attached to the shrouds or baffles. Be sure they are disconnected so they are not damaged.

The Governor

In order to keep the engine running at about the same speed as it encounters varying load conditions (such as on a lawn mower), a device is added called a governor. On most small engines the governor will be either a mechanical type or an air vane type. The operation of each are described and shown in the following pictures.

Air Vane Type Governor



- Air from flywheel fan blows the governor blade over.

- Governor spring tends to hold the throttle valve closed with tension cable from the throttle lever set by the hand throttle control.

- When the force on the governor blade becomes equal to the tension set in the governor spring, the throttle valve will be held in that position, thus maintaining a constant engine speed.

Hand Speed Control Lever
- push to increase governor spring tension, thus decreasing engine speed.
- pull to decrease governor spring tension, thus increasing engine speed.

Mechanized Type Governor
The mechanical type governor operates on the same balance of forces principle as the air vane type governor. The main difference between the two types is the source of the governor force. On the air vane type, the force comes from air furnished by the flywheel fan. On the mechanical type, the operating force comes from centrifugal weights.
- The governor spring tends to hold the throttle valve closed with tension set by the hand throttle control.

- As the shaft rotates centrifugal forces push the governor weights away from the shaft. This movement of the weights pushes the governor sliding collar up the shaft. The movement of the collar pulls the throttle arm up thus opening the throttle valve.
- When the force on the governor weights becomes equal to the tension set in the governor spring, the throttle valve will be held in that position, thus maintaining a constant engine speed.

1. Check your engine for trash and dirt on the cooling fins. Clean fins if needed.
2. Check air shroud that directs the air from the flywheel on to the cooling fins. Replace any baffle that might be missing.
3. Make different hand throttle control settings with the engine running and note the different position the governor control linkage takes.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Understand cooling systems.
- Understand speed control

Smooth Running 1: Flywheel removal and Key replacement

Objectives:
Members will be able to locate and remove the flywheel and replace the key.

Tools Required:
- Socket set
- Pliers
- Lubricating fluid
- Flywheel puller
- A small wooden block
- Hammer

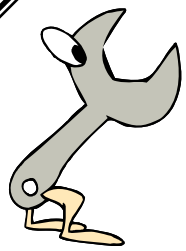
Flywheel removal
- Remove the shroud which covers the flywheel
- Remove the armature as discussed in "Activity 2"
- Remove the nut on top of the flywheel
- Pour some lubricating fluid down the bolt
- Place the puller on top of the bolt and attach it to the flywheel
- Note: It might be necessary to have to "Tap" the holes in the flywheel
- Note: Do not try "lever" the flywheel up by striking it with a hammer. If you damage the flywheel it will not be balanced and can cause serious problems
- Carefully tighten one bolt then the other until the flywheel comes off

The Flywheel key

- The Flywheel key is designed to sheer off if something interferes with the crankshaft operation.
- The Flywheel key is located on the crankshaft right below the flywheel. If it has been damaged only half of it will be there (the other half may be in the flywheel.)
- Using the pliers remove the parts of the key

Flywheel replacement

- With the new key in place line up the notch in the flywheel over the key and firmly press the flywheel over the crankcase
- Place a wooden block over the flywheel and tap it with the hammer, work from side to side to be sure the flywheel goes on straight.
- Reinstall the nut on the crankshaft
- Reinstall the armature and the shroud
- Without the spark plug, give the engine a few test cranks to make sure it is operating properly.
- Replace the spark plug and test fire the engine.



Smooth Running Program Reports

- Have members determine the type of governor on their small engine and make a sketch of the governor linkage in "Speed Control" on page 6.

Tips
Quality Equation

Teaching evaluation and decision making skills are giving life skills to young people beyond the mechanics tool. The 4-H program is committed to the personal development of youth.

How Small Engines Work – Electric Starters & Batteries

Science Background for Leaders

You have already learned about manual starters - rewind, rope-pull, and windup. Here's another starter, one that uses less manual power and more electric power.

There are two basic types of electric starters:

A. 120V AC starter (plug in to wall)
B. 6V or 12V DC starter (battery powered)

Starter/generator on a four cycle small engine

A. **The Alternating Current Starter (120 Volt AC)**

Alternating-current starters are operated on 120-volt current from your home wiring system. An extension cord is used to connect the starter to a convenience outlet.

The 120-volt alternating-current starting system consists primarily of the following:

- An electric motor - power to operate the starter.
- An on/off switch.
- An extension cord to reach the power source.
- A starter-drive mechanism - to engage the starter with the flywheel for cranking and for disengaging when the engine starts.

Basically, alternating-current starters can be classified according to the type of drive (engaging and disengaging) mechanism.

There are three types:

1. Cone-Shaped Friction Clutch
2. Bendix
3. Split-Pulley Clutch

1. Cone-shaped friction clutch:

To operate this type of starter, press the switch control button down until the electric motor starts. Hold it in this position until the electric motor gains speed; then push the entire starter housing down until the cone-shaped clutch is engaged. This engages the starter to the flywheel and cranks the engine.

When the engine starts, release the control knob. The starter housing is lifted by the starter-release spring, and the switch is turned off by the switch release spring.

2. Bendix-type starter drive:

This is a common type used on direct-current starters on all types of automobile and tractor engines. It is called "bendix" from the name of the inventor. Here is how it works.

When you turn the switch on the electric motor starts. The pinion gear does not turn because of inertia. As a result, it moves endwise on the threaded shaft until it engages the flywheel gear. When this happens, the endwise motion stops and the pinion gear rotates with the shaft. The starter is engaged. The flywheel turns and cranks the engine.

When the engine starts, the starter switch is turned off. The pinion gear rotates faster than the starter shaft because it is now being driven by the flywheel. It spins back on the threaded shaft away from the flywheel gear, thus disengaging itself. The heavy spring on the starter shaft is used to help relieve the shock on the starter parts as the starter cranks the engine.

3. Split-pulley clutch:

This type is engaged by friction, but it is done automatically. The pulley halves are separated when the starter is not engaged. They close when the starter is engaged.

When you turn on the switch, the electric motor starts. The upper half of the pulley turns with the motor shaft. The motor shaft turns inside the lower half of the split pulley. The lower half does not turn momentarily because of inertia (resistance to changing position). As a result, the pin in the starter shaft pushes against the incline on the pulley and forces the lower pulley half upward. This closes the gap between the pulley halves. When this happens, the belt tension is increased; and friction is developed between the pulley flanges. The drive pulley rotates. The starter is engaged and cranks the engine.

When the engine starts and the starter switch is turned off, the electric motor stops. With the engine running, belt tension applied to the split pulley forces the movable (lower) half back down, thus releasing the belt tension and the starter. The belt rides loose in the open split pulley while the engine is running.

B. **The Direct Current Starter (6 Volt or 12 Volt DC)**

The direct-current starter on your small engine is similar to the one you have on your tractor, truck or automobile. It operates on power supplied by a storage battery (6 or 12 volts). The charge on the storage battery is maintained by an engine-driven generator. The generator may be (1) a separate direct-current unit, (2) a separate alternating-current unit - with a means for converting the alternating current to a direct current - or (3) it may be a combination starter-generator unit.

The combination unit is by far the most popular for small engines. It is more compact and self-contained, and does not require a disengaging mechanism.

The direct-current starter-generator system consists of the following:
- A direct-current starter or a combination starter-generator.
- A storage battery.
- A direct-current generator and voltage regulator, or an alternating-current generator and rectifier for changing the alternating current to direct current.
- A starter switch.
- An ignition switch.
- A generator warning light, or an ammeter (most systems).
- A starter-drive mechanism - a belt is used on the starter-generator combination, and it is never disengaged from the engine. Direct-current starters - without a built-in generator - normally have a bendix type of drive mechanism for engaging and disengaging the starter and the flywheel.
- Connecting wires.

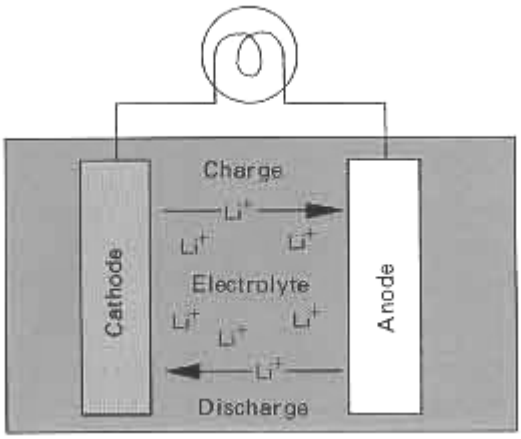
A 12-volt combination direct-current starter-generator is the most common type of electric starter. When the starter switch is on, the electric circuit is completed between the starter-generator and the battery. Current flows from the battery (negative to positive) through the ground wire to the starter-generator. The starter-generator acts as an electric motor. It turns the engine crankshaft through a belt drive.

When the engine starts, the starter switch is released. The starter-generator is not disengaged as with other starters. Instead, the engine drives the starter-generator. Then the starter-generator acts as a generator and produces electrical energy for the ignition system, for the lights - if installed - and for recharging the battery. The amount and the rate of charge to the battery is controlled by a current voltage regulator.

A voltage regulator controls the amount of current going from the generator while the engine is operating. The regulator protects the generator from excessive output and possible failure. It also prevents the battery from becoming overcharged. Without some means of control, overcharging could cause the battery to get too hot, and the water in the electrolyte would boil away.

THE BATTERY: How It Works

To care for a battery you need to understand its construction and how it works. The picture below shows the two main parts of a battery.



A storage (lead acid) battery contains metallic lead grids to which lead oxide is added. The plates are electrochemically treated in a dilute solution of sulfuric acid. This treatment causes the lead oxide (Pb0) in the positive plates to convert into lead peroxide (Pb02). The lead oxide in the negative plates is converted into metallic spongy lead (Pb). Groups of positive and negative plates are assembled alternately with separators between each two plates.

The separators are plastic or cellulose and are not normally affected by the acid. Each such grouping of positive and negative plates forms a 2-volt "element" when immersed in sulfuric acid. Each element is assembled in a hard rubber or plastic "cells". The elements are connected in series (positive to negative plates) by means of welded-on lead connectors. A battery of 6 such cells gives a nominal voltage of 12.

Operators' manuals warn that you should keep the battery liquid level above the level of the plates. When portions of the plates and separators are exposed to air, they dry out. Those portions that dry lose their ability to function and may become permanently damaged. Consequently, your battery loses that much of its capacity, which means less power for cranking. It also means shorter battery life since water only is lost through evaporation and forming of gas. The electrolyte remaining becomes very strongly concentrated and may break down the separators and plates during the time the liquid level is low.

Your battery will require more water (a) when it is being overcharged or (b) when the weather becomes hotter. Most batteries are now sealed units and do not need to have water added.

The capacity of your battery in cold weather is greatly reduced. Even a fully charged battery at -18°C (0"F) has only 40 per cent of the capacity it has at 20°C (70°F). That is the reason a weak battery may give fair service until the weather turns cold. Then it appears to go bad all at once.

Cleaning the battery is important. As you use the engine, dirt, moisture and acid gradually accumulate on top of the battery. Acid spray is carried out of the battery with the gas that is liberated while the battery is being charged. It settles on the battery top and provides a damp surface where dust and dirt will cling. It also gets on the battery posts and terminals and equipment and causes corrosion.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Know how electric starters work.
- Know the types of electric starters.
- Know how batteries work.
- Clean a battery.

Smooth Running 1: Battery Care

Checking the Battery Frame and Cable Connections

Check for loose terminal connections on the battery posts and for loose hold-down clamps on the battery.

If the terminals are loose, there is resistance to the flow of current at this point so that equipment supplied by the battery does not get the full benefit of the battery voltage. The starter draws a tremendous amount of current so it is essential to have a good connection

If the hold-down clamp is loose, the battery is free to bounce which in turn may damage the plates and can cause internal short circuiting. It is also possible to tighten the hold-down clamps too much and put the battery in a bind which can result in breaking the case. Tighten just enough to prevent movement of the battery.

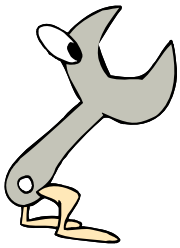
Storing the battery

When storing a battery for the winter is should be in a cool dry place and should be charged up every 90 days. It is best to charge a battery using 6 amps or less. Many battery outlets will have an automatic charger that will constantly keep the battery at full charge.

Cleaning the Battery

1) Disconnect cable and ground strap from battery terminals if they are corroded.
   - Loosen and remove ground strap first. This prevents short circuits in case you accidentally touch metal with the wrench used to loosen the ground strap, or if you lay a wrench or screwdriver on the battery in such a way as to contact the opposite battery terminal and some part of the frame.
   - If you remove the battery, note which cable goes to which terminal so you will know how to reinstall it. If you connect it wrong, there is a danger of burning out the voltage regulator on generator systems that use an alternator. A wrong connection will only take a second to burn out the alternator.

2) Clean cable clamps and battery post.
   - A wire brush may be used on outside surfaces. Sandpaper is satisfactory for cleaning inside of clamps. Pay special attention to inside of cable clamps and outside of battery posts. Special battery connection cleaning tools are available. CAUTION: Use safety glasses to protect your eyes when using a wire brush.
3) Remove loose dirt and corrosion particles from top of battery with a brush.
4) Brush soda-and-water mixture on top of battery, on posts and on clamps.
   - Use approximately two tablespoons of baking soda in a pint of water. Mix thoroughly and apply on the battery. This will react with the acid and cause considerable foaming. Apply until foaming stops.
5) Wash away residue with clean water.
   - Remove residue that may have lodged on battery frame or parts of engine and equipment.
   - Breather caps may be plugged with toothpicks to prevent water and dirt from going into the battery.
6) Dry top of battery with a clean cloth.
7) Reconnect power cable and ground strap.
   - Connect power cable first to help avoid grounding the battery with your tools.
   - Do not hammer the clamps into place on the battery posts. You can break the seal around the battery terminal or cause a crack in the cell cover. In either instance the electrolyte will work out on top of the battery and hasten battery failure.
   - If the jaws of the clamp meet before the clamp tightens adequately on the battery post, take your knife and cut a small amount of metal from between the jaws.
8) Apply a coating of petroleum jelly (Vaseline) or silicone spray to post and cable-clamp connections.
   - This helps protect against further corrosion.



Smooth Running Program Reports

- Have members discuss and list the advantages and disadvantages of an electric starter system in "Pros & Cons of Electric Starters" on page 7.

Q Tips
Quality Equation

Teaching evaluation and decision making skills are giving life skills to young people beyond the mechanics tool. The 4-H program is committed to the personal development of youth.

Troubleshooting

Science Background for Leaders

Now that you have learned how a small engine operates, you can use your knowledge in finding and curing the ills your engine might develop. This procedure is called troubleshooting.

Remember these important points when troubleshooting:

- A supply of fuel and air of the correct amounts must get into the combustion chamber at a precise time.
- This fuel and air mixture must be compressed into a fraction of its entry volume.
- An electric spark must ignite the fuel air mixture at a precise time.
- Troubleshooting then would be finding out which function is not happening as it should, then finding out why it is not happening correctly.

There are several steps you could follow in diagnosing engine trouble. This outline does not need to be followed in every detail. A sharp observation of the circumstances leading up to the trouble can mean a shortcut to finding out the problem. However, the troubleshooting procedure suggested here can help you find the cause of trouble.

If engine will not start or is hard to start

There are several things that could be wrong if an engine will not start or is hard to start. The following check-out procedure will assist you in locating the trouble.

1. Check engine compression.
Crank the engine slowly to check engine compression. One cylinder, four-cycle engines should have a marked resistance to turning on every other revolution. One cylinder, two-cycle engines should have compression resistance on every revolution.

If little or no engine compression resistance is felt.

a. Check to see if the spark plug is screwed tightly into the cylinder. If spark plug is cracked, it will also cause compression loss. The spark plug gasket can be defective and leak even though the spark plug is in tight.
b. Check the cylinder head gasket for possible leaks. Also, check for loose head bolts or possible cracks in the cylinder head.
c. On four-cycle engines it could be oil has drained completely away from the piston, thus eliminating part of the compression seal. Check lubrication oil supply. If piston does appear to be dry, turn engine on its side and rotate crankshaft through a revolution or two.
d. Broken internal engine parts could be causing the problem, such as a valve stuck open, rings stuck in the piston groove, broken rings, or a scored cylinder.

In most cases, compression will be good enough to create resistance to rotating of the crankshaft. If it is, then proceed to the second check.

2. Check engine ignition system.
First, make sure ignition switch is in run position. Remove spark plug wire from spark plug terminal. Hold the spark plug end of the wire about 2 mm. away from cylinder or any metal part of the engine. On wires equipped with a rubber cover insert a screw or bolt in the boot so current can be brought to within 2 mm. of the ground metal. If you have a test plug, use it instead of this grounding procedure. Crank engine with spark plug wire in this position. If the ignition system is working properly, a bright blue spark should jump across the 2 mm. space. If you get no spark or a weak yellow spark, then you will know to check the magneto ignition further. When making the additional magneto tests, the following procedure is recommended:

a. Thoroughly inspect spark plug wire for places where wire is exposed through worn or broken insulation.
b. Next, inspect the magneto breaker points. If they are dirty, clean them. Turn engine to make sure the points open and close. Remember the points open to fire the spark plug.
c. Then, check the spacing of the points when they are open. This gap is from .018 to .022 inches on most engines. Use the gap setting recommended for your engine. If the surfaces of the contact points are badly pitted, the points should be replaced. Check breaker cam. It should be tight on the shaft and not excessively worn.
d. Check the air gap between the permanent magnets and the coil core. Use the specific recommendations for your engine. If you do not have the gap setting, remember this gap should be as close as you can get it without metal to metal contact.
e. Check condenser connections to make sure they are tight. Check condenser with test light. Connect test light between engine ground and condenser lead wire. If light burns, condenser is shorted out and should be replaced. It is possible the magneto coil could be defective. Since the coil is difficult to check without a coil tester, make sure you have done your checks carefully before installing another coil.

If you observed a bright blue spark when you checked the magneto, then remove the spark plug and run it through the following checks:

1. With spark plug wire attached to plug, lay spark plug on cylinder head where metal of plug is in contact with metal of engine. Crank engine and observe spark across plug. If a bright blue spark jumps, then proceed to next general step of checking the fuel mixture. If you get no spark or a weak yellow spark, then proceed with checking the spark plug.

2. Clean and adjust spark plug electrodes to the recommended spark gap. Then check for spark again. Pay close attention to the condition of the plug before cleaning as it can give you a clue as to the cause of plug fouling (oil fouling, overheating, carbon burning). If this does not give good spark, get a new plug.

If compression and ignition check out okay, then proceed to Check 3.

3. Check fuel mixture to the cylinder.
Remember fuel and air mixed in the right proportions must reach the cylinder at a precise time if the engine is to start and run properly.

a. Check the fuel tank to be sure it contains a supply of fresh fuel. In the case of a four-cycle engine, fresh clean gasoline. In the case of a two-cycle engine, a fresh clean supply of the proper mixture of oil and gasoline. Be sure fuel line cut off valve is open.

b. Inspect air cleaner to make sure air can pass freely through it. If necessary, service the air cleaner.

c. With choke fully closed, try to start engine. If after several starting tries the engine does not start, remove the air cleaner and inspect the carburetor throat at the throttle valve. The carburetor throat should be damp with fuel.

d. If carburetor throat is not wet, disconnect the fuel line at the carburetor to see if fuel is flowing through the line. If no fuel flows, clean out the fuel tank, fuel line, fuel filter, if any, and shut off valve so fuel will flow to carburetor.

e. If fuel flows at the carburetor, then check the carburetor. First, check carburetor setting as suggested under carburetor section. If this does not correct the problem, then check to see if carburetor choke valve is stuck. Also, check the throttle control valve to see that it functions If these things fail to turn up the trouble, then look inside the carburetor at the float, the float control valve, the main and idle jets.

Some engines are designed to use the weight of the equipment they are driving as a part of the flywheel momentum. The rotary lawn mower is an example. The rotating weight of the mower blade fills out the momentum necessary to carry the engine through the compression stroke for good engine operation. Without the blade being solidly attached to the crankshaft, the engine will not start. Sometimes hard starting can be traced to the blade slipping at the safety slip clutch. In this case, tighten the slip clutch.

If engine starts, loses power, then stops

This engine failure is usually caused by not enough fuel, but it may be caused by ignition problems.

Use the following steps:

1. Make sure fuel tank cap is allowing air to enter the tank as fuel is drawn out.

2. If fuel cap proves not to be the cause of the trouble, check for clogged fuel filter, fuel lines, or fuel cut off valves. Clean and service these parts.

3. On two-cycle engines check the reed valve. If this valve is not holding the compression in the crankcase, insufficient fuel will get into the cylinder. Also check the gasket seals on the crank case. Compression leaks from the crankcase will give the same operating difficulty as a reed valve not working.

4. Also, on two-cycle engines, clogged exhaust ports can cause fuel starvation in the cylinder. Unburned carbon, from overly rich fuel mixture or too much oil in the fuel mixture, tends to build up on the exhaust port. This build up restricts the escaping exhaust gases which prevents fresh fuel gases from filling the cylinder. On most engines, remove the muffler to expose the exhaust port. Scrape carbon from ports with a plastic or wooden scraper. Do not use a metal scraper because the piston could be damaged.

5. If these checks do not correct the problem, clean, inspect, and repair, if necessary, the internal parts of the carburetor.

6. With the fuel system eliminated as the trouble source, make these checks on the ignition system. Immediately after the engine stops, check the ignition spark. If no spark is present, you will likely need to replace either the coil, condenser, or points. Also, on four-cycle engine check the compression immediately after the engine stops. Little or no compression caused by a sticking valve could be the cause of engine loss of power and stopping.

Engine Overheating Causes:
1. Engine being overloaded.
2. Air movement to cooling housing fins restricted by trash in the blower.
3. Air not directed to housing cooling fins because of missing shields.
4. Dirt on the cooling fins acts as an insulator.
5. Restricted exhaust.
6. Carburetor fuel mixture too lean which causes slow burning of the gases in the cylinder.
7. Timing slightly off. This can be caused by improper breaker point gap.
8. Low oil supply in four-cycle engines. Two-cycle engines operated with little oil in the fuel mixture.

The cure for each of these causes is obvious.

Additional problems and remedies

- *Problem*: Engine will not start or is hard to start.
  Possible causes:

    1. Fuel tank is empty or shutoff valve is closed, or fuel line or fuel tank cap vent is clogged.
    2. There is water in the fuel.
    3. Carburetor is over choked.
    4. Carburetor is improperly adjusted or needs service.
    5. Ignition system or its wiring is defective or ignition switch is off.
    6. Deadman or other cut-off switch is open or defective.
    7. Spark plug is fouled, improperly gapped, or damaged.
    8. Engine compression is poor.
    9. Operator needs to read user manual.

- *Problem*: Engine starts easily but dies after a few seconds.
  Possible causes:

    1. Fuel tank is empty or shutoff valve is closed, or fuel line or fuel tank cap vent is clogged.
    2. Carburetor is over choked.
    3. Carburetor is improperly adjusted or needs service.

- *Problem*: Engine misses under load.
  Possible causes:

    1. Spark plug is fouled, improperly gapped, or damaged.
    2. Breaker points are pitted or improperly gapped, breaker arm is sluggish, or condenser is bad.
    3. Carburetor needs adjustment or service.
    4. Fuel line, fuel filter, or fuel tank cap vent is clogged, or fuel shutoff valve partially closed.
    5. Valves not adjusted properly or valve springs weak.
    6. Exhaust ports blocked (2 stroke).

- *Problem*: Engine knocks.
  Possible causes:
    1. Magneto is not timed properly.
    2. Carburetor is set too lean.
    3. Engine has overheated.
    4. Carbon buildup in combustion chamber.
    5. Flywheel is loose.
    6. Connecting rod is loose or worn.
    7. Cylinder is excessively worn.
- *Problem*: Engine vibrates excessively.
  Possible causes:
    1. Engine is not mounted securely.
    2. Blade or other driven equipment is unbalanced.
    3. Crankshaft is bent.
    4. Counterbalance shaft is not timed correctly.
- *Problem*: Engine lacks power (possibly after warmup).
  Possible causes:
    1. Old gas, bad spark plug, very thick/dirty oil.
    2. Choke is partially closed.
    3. Carburetor needs adjustment or service.
    4. Ignition not timed correctly.
    5. Air filter is clogged.
    6. There is a lack of lubrication.
    7. Valves are not sealing properly.
    8. Piston rings are not sealing properly.
    9. Head loose or head gasket blown or damaged.
    10. Exhaust ports blocked (2 stroke).

- *Problem*: Engine operates erratically, surges, and runs unevenly.
  Possible causes:
    1. Fuel line or fuel tank cap vent is clogged.
    2. There is water in the fuel.
    3. Fuel pump is defective.
    4. Governor is not set properly, sticking, or binding.
    5. Carburetor needs adjustment or service.
- *Problem*: Engine overheats.
  Possible causes:
    1. Magneto is not timed properly.
    2. Carburetor set too lean.
    3. Air intake or cooling fins are clogged.
    4. Shroud or blower housing missing.
    5. Excessive load.
    6. Insufficient or excessive oil.
    7. Improper oil viscosity (4 stroke) or mixture (2 stroke)
    8. Valve clearance is too small.
    9. Excessive carbon build up in combustion chamber.
- *Problem*: Crankcase breather passing oil.
  Possible causes:
    1. Too much oil in crankcase.
    2. Engine speed is excessive.
    3. Oil fill cap or gasket is damaged or missing.
    4. Breather mechanism is dirty or defective.
    5. Piston ring gaps are aligned.
    6. Piston rings are worn.

- *Problem*: Engine backfires.
  Possible causes:
    1. Carburetor set too lean.
    2. Magneto is not timed correctly.
    3. Valves are sticking.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

- Know the basic steps in troubleshooting.
- Know the procedures in troubleshooting.

Smooth Running 1: Piston ring inspection and replacement

Objective:
Students will be able to demonstrate:

- The proper procedure to expose the piston
- Removal of the piston rings and replacement of the Piston Rings
- Replacement of the piston.

Tools required

- Socket set
- Torque wrench
- Feeler gauge
- Wooden or plastic scraper
- Emery cloth
- Pencil & thin cardboard
- Materials used for draining oil
- Solvent (optional)
- Wire brush
- Piston ring compressor
- Piston ring expander

Piston Removal

- Expose the crankcase (bottom end of the piston)
- Remove the cylinder head
- Rotate the piston so it is at TDC (Top Dead Centre) this will make sure that the valves are both closed.
- Remove the two bolts that hold the piston to the crankcase

- Using a wooden implement push the piston up through the cylinder (If you use a metal tool to push the cylinder you run the risk of scoring the side of the cylinder wall).

Cleaning the surfaces

- Using the piston ring expander remove the rings
- Clean the end of the piston with a scraper or wire brush
- Clean the remnants of the gaskets off the cylinder head

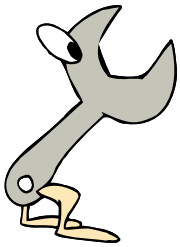
Re-installing the piston

- Using the piston ring expander or your fingers slide the rings one at a time over the piston
- Note: Some pistons will have three rings others will have two
- Note: Be sure to get the rings in the right order
- Note: Be sure the ends of the rings do not line up. The manufacture of the rings will have specific instructions on how the ring ends should look
- Place the piston ring compressor over the piston and compress the rings by turning the key
- Lightly oil the sides of the cylinder
- Place the piston over the cylinder
- Tap the top of the piston with a non metallic implement (like the butt end of a hammer) until the piston slides into the cylinder
- Note: This is tricky! It may take you several tries before getting the piston in properly
- Replace the bolts that hold the piston rod to the crankcase
- Replace cylinder head and the crankcase cover
- Crank the engine without the spark plug to ensure proper movement
- Test fire the engine

Smooth Running 2: Troubleshoot the problem

Get parent or 4-H Club leader to deliberately do something to your engine so that you can troubleshoot the problem they created. They might do one or more of the following:

- Partially unscrew a spark plug.
- Replace a good spark plug with a defective one.
- Ground the spark plug wire.
- Put an obstruction in the magneto breaker points to hold them open.
- Plug the air intake at base of air cleaner.
- Block the fuel flow some place in the fuel lines.
- Disconnect the linkage to the throttle valve.
- Short out the spark plug.
- Drain all the fuel out of the engine.
- Disconnect the magneto condenser.
- Use your imagination for many more.



Smooth Running Program Reports

- Have members complete the "Troubleshooting" questions on page 7.

Q Tips
Quality Equation

Some engine overhauls are successful, others not so successful. Use the testing of your engines as an opportunity to promote and encourage the quality characteristic traits of sportsmanship, caring and teamwork. This will help ensure the project is a positive experience for all members.

Storing Small Engines

Science Background for Leaders

Now that your small engines are running well, you want to keep them doing so.

When properly prepared for storage, engines have been known to start and run perfectly after remaining in storage for five years or longer. You probably never expect to store an engine this long but if you do not plan to use your small engine for six months or more, you should protect it from these things:

1. MOISTURE that collects on the outside of the engine and penetrates into electrical system and the inside of the engine.

2. DUST AND DIRT which accumulate on the outside of the engine.

3. CORROSION of any metal and iron parts such as the valves, cylinder, piston and piston rings.

4. GUM which develops from left-over fuel in the fuel system.

5. PHYSICAL DAMAGE - damage to the engine due to heat, cold and abuse.

Preparing your engine properly for storage and keeping it in a safe place may also prevent injury to some one who may trip and fall over it. There is also a danger of children and other inexperienced persons starting and operating the engine and equipment and getting hurt. This is especially true with engines on such machines as chain saws, portable generators, small tractors, mowers, and air compressors.

The end of the season is always a good time to check and clean your engine because you can:
1) determine what repairs need to be made,
2) remove dirt and grime which tend to collect more dirt during storage.

Key Objectives Highlighted by this Project Meeting:

By the end of this meeting, members should be able to:

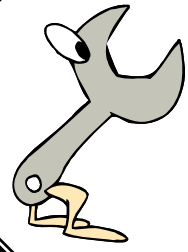
- Know the importance of proper storage.
- Know the steps in storing small engines.

Smooth Running 1: Off season storage

Preparing your small engine for off-season storage:
1. Remove fuel from tank;
    - operate engine until it runs out of fuel
2. Check and clean engine.
3. Check and clean air cleaner.
4. Coat the inside of the engine with oil (through spark plug hole).
5. Drain and replace oil (4-stroke engines).
6. Clean and recap spark plug.
7. Drain carburetor, fuel strainer and all gasoline lines.
8. Place piston on compression stroke.
9. Repaint all exposed steel or cast iron surfaces.
10. Cover engine with a plastic sheet.
11. Store engine in a safe, dry place.

Smooth Running 2: Celebrate

Celebrate your successful overhaul by taking an "After Photo".



Smooth Running Program Reports

- Have members take and mount an "After Photo" of their restored engine on page 8.

Quality Tips

It is important to recognize and to value the specific skills and personal growth that 4-H members accomplish. Celebrate their year long learning and achievements.